Dynamic Field Test of Wooden Signposts

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The paper reports results of 10 tests of wooden signposts to determine their breakaway characteristics when various planes of weakness were introduced into the posts. Different sizes of holes or notches as planes of weakness were introduced into the posts. Dynamic tests, simulating automobile collisions, were accomplished by towing the test vehicle to 40 mph and releasing it 100 ft prior to impact with the post. Test results indicate that holes are equivalent to notches for reducing the post section at the ground line, but the plane of weakness introduced under the sign did not function. Results also indicate that safety would be provided if signs were mounted with a clearance of 6 to 7 ft between the ground line and the bottom of the sign and if stronger bolts were used to connect the sign to the post. Posts with 4- by 4-in. cross sections do not require a plane of weakness.

•THE PENNSYLVANIA Department of Highways currently uses wooden signposts when the sign area is less than 80 sq ft and when the sign location is in close proximity to traffic, such as in a gore. The 6- by 6-in. and 4- by 4-in. posts currently used are considered undesirable because they have no built-in planes of weakness. The 6- by 8-in wooden posts that support extruded aluminum channel signs do have notches 2 in. deep. This type of sign is used especially for gore installations or Interstate routes. Further information was desired on the performance of these posts in a controlled test. The main consideration in introducing a plane of weakness into the existing 6- by 6-in. and 4- by 4-in. posts was to sufficiently weaken the posts to prevent excessive damage to vehicles involved in collisions with the signs, but not to critically reduce the capacity of the posts to resist wind loads. Information was also desired on the performance of these signs after alteration in a controlled test.

The site of the field tests was a macadam runway at the airport in Mt. Pocono, Pennsylvania. The tests were conducted July 10, 11, and 12, 1968.

The principal objectives of the tests were (a) to determine if holes drilled in the post are as effective and safe as notches, (b) to determine the breakaway characteristics of posts with these different types of planes of weakness, and (c) to improve the design of wooden signposts.

PROCEDURE

The test site was a portion of the paved runway approximately 1,100 ft long by 100 ft wide. The tests were conducted near one edge of it (Fig. 1).

Instrumentation

A crash was simulated by towing an automobile and releasing it prior to collision (Fig. 2). The tow rope from the side of the truck had to be offset to maintain a safe distance between the truck and the post to be impacted. This was accomplished by fastening the rope to the front of the truck near the door and threading the rope around a 4- by 4-in. wooden post that was bolted to the back bumper. This portion of the post was cantilevered horizontally and extended 6 ft from the side of the truck.

The post (outrigger beam) was in two 6-ft pieces connected by a hinge at the side of the truck. One part of the post was bolted to the truck bumper and the other piece was

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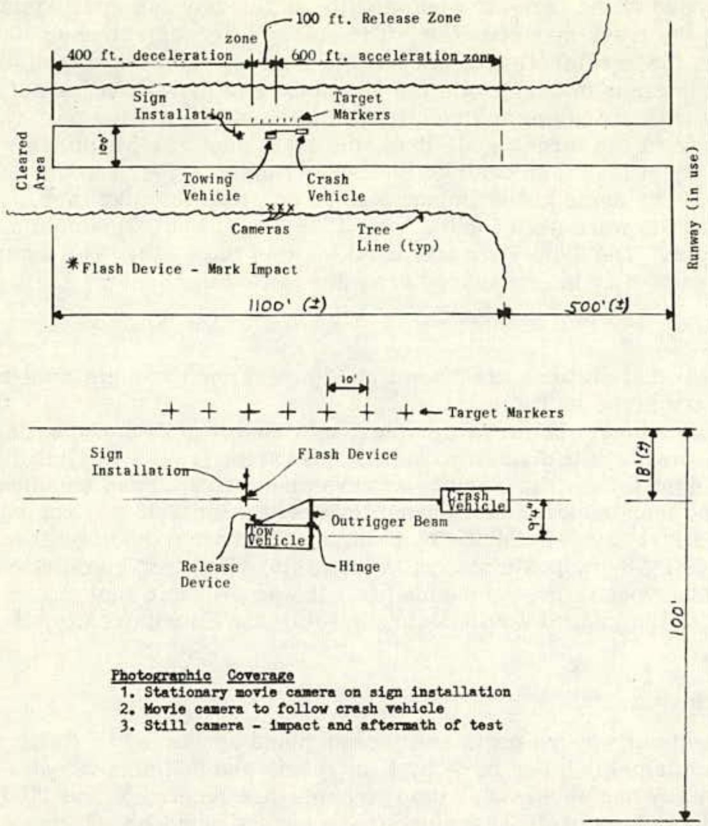

Figure 1. Test site.

cantilevered out from the side of the truck. This hinge allowed the cantilevered piece to rotate into the bumper when the tow rope was released. The release device (Fig. 3) was mounted near the door on the passenger side and was supported by a steel channel bolted into the truck frame. This device included the housing, lug, and direct pull release; the 1-in. tow rope was tied through an eye in the lug. The rope was tied and centered on the bumper supports of the crash vehicle. After release, the automobile dragged the rope with lug attached through the crash scene. The steering wheel of the automobile was tied by rope to the seat belt to steady the steering but allow some self-adjustment.

Figure 2. Device used to accelerate test vehicle.

Figure 3. Release device.

An average speed of the truck and automobile at release was approximately 40 mph as registered on the truck speedometer. The automobile was released 100 ft before impact; however, the deceleration of the vehicle was negligible in this distance. No direct attempt was made to decelerate the automobile after impact for safety reasons.

The accuracy with which the automobile could be guided into the post varied from direct hit to 6 ft from the target post, thus, the right post was hit in some cases. Although this may seem less than desirable, such a random pattern would actually occur along a highway. The angle of the impact was 90 deg with the sign face.

Three automobiles were used for the test: 1964 Ford, 1950 Oldsmobile, and 1957 Ford station wagon. The 1964 Ford was used for 8 of the tests. The bumper height of the automobiles was 15 in. measured from the ground.

Signpost Installation

The 10 signpost installations are shown in Figure 4 and their measurements and characteristics are given in Table 1.

A truck-mounted auger, 22 in. in diameter, was used to drill the holes through the runway to install the posts. The diameter of the holes varied from 2 to 3 ft in diameter, and the depth from 4 to 5 ft. The signposts were prefabricated and embedded in a 1-ft layer of stone and then backfilled to ground level with sand that was compacted by hand tamping. Normally 4- by 4-in. or 6- by 6-in. signposts may be set either in ground or in concrete and 6- by 8-in. posts always in concrete. The test installations were representative of both types of post embedments. It was probable that more lateral movement of the post in the ground would occur, but this should not greatly affect the test results.

Related Research

A report on tests of wooden posts and timber poles conducted in California (1) recommends 2½-in. diameter holes in 6- by 8-in. posts and no holes in poles less than 7 in. in diameter. When necessary, the two holes are located ½ and 1½ ft from the ground line, and no plane of weakness under the sign is supplied. If these recommendations were followed in Pennsylvania, a plane of weakness would not be necessary in the 4- by 4-in. and 6- by 6-in. posts.

A test was conducted on two 6- by 8-in. Pennsylvania posts with a 5- by 6-ft sign by the Texas Transportation Institute (2) in 1965. Both posts were struck and, after initially shearing, hit the roof of the automobile. Notches were the safety features

TABLE 1

MEASUREMENTS AND CHARACTERISTICS OF SIGNPOST INSTALLATIONS

Test	Size of Posts (in.)	Length of Posts (ft)	Size of Sign (ft)	Area of Sign (sq ft)	Size of Plane of Weakness (in.)[a]		Material
					Bottom	Top	
1	6 by 6	14	5 by 10	50	¾ N	¾ N	Stock material
2	6 by 6	14	5 by 10	50	1½ H	1½ H	Stock material
3	6 by 6	14	5 by 10	50	1½ H	1½ H	Stock material
4	6 by 6	14	5 by 10	50	1½ H	2H	Stock material
5	4 by 4	14	5 by 5	25	½ N	½ N	New post lumber
6	4 by 4	14	5 by 5	25	1 H	1 H	New post lumber
7	4 by 4	14	5 by 5	25	1 H	1 H	New post lumber
8	4 by 4	14	5 by 5	25	–	–	New post lumber
9	6 by 8[b]	15½	4 by 10[b]	40	2½ H	2½ H	New post lumber
10	6 by 8[b]	14 7/12	4 by 10[b]	40	2 H	2 N	Stock material

[a]H = Hole, N = Notch. [b]Extruded aluminum channel sign.

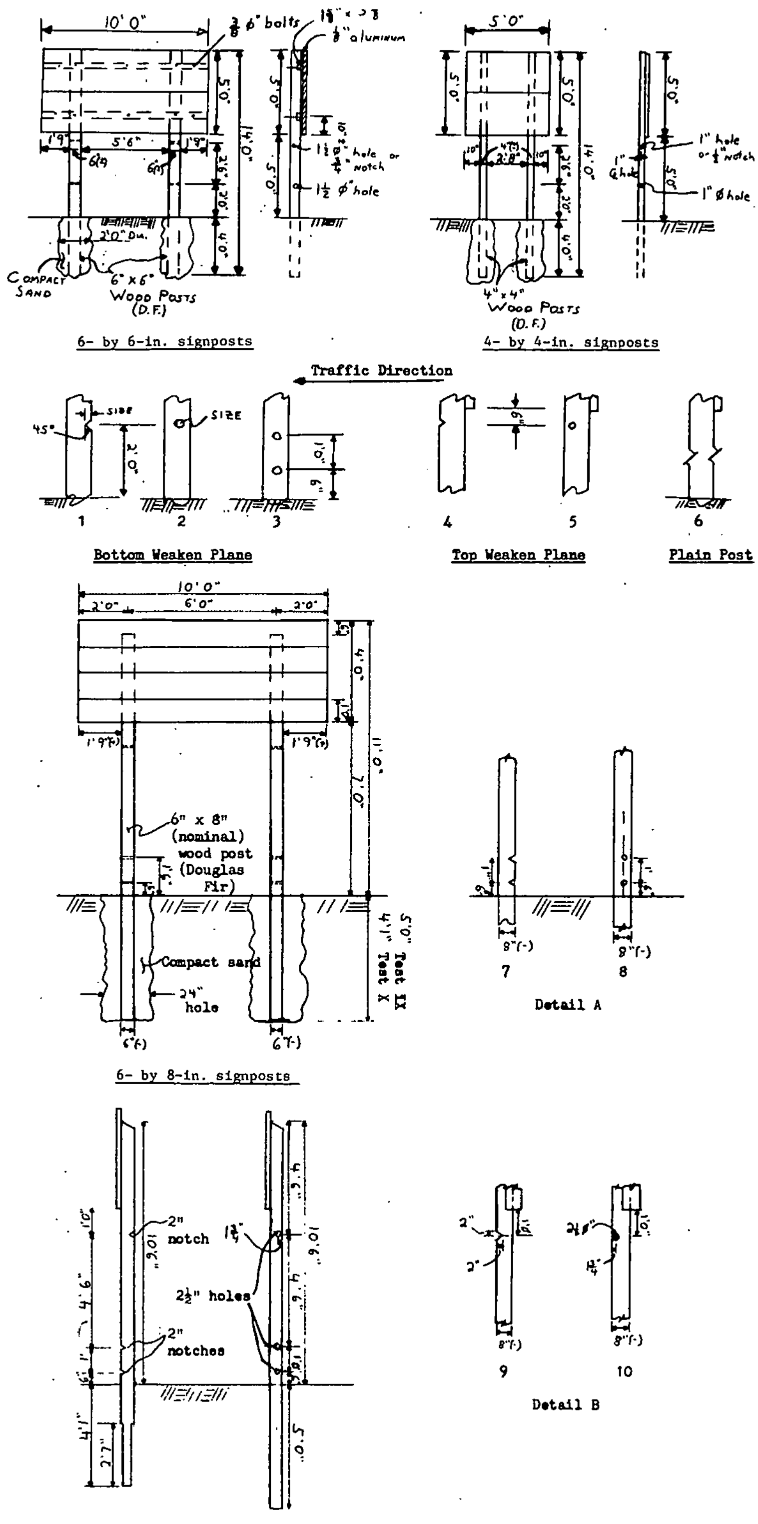

Figure 4. Signpost installations.

induced into the post, and no sign of failure was evident under the message board. In addition, the sign pulled loose from the connection with the posts.

Other Design Considerations

Signpost installations must be strong enough to resist the wind even when they have induced planes of weakness to satisfy certain safety criteria. Because bending is the primary stress at the base of the post for wind load and shear stress is the primary factor for safety, a hole at the center of the post through the post parallel to the sign face will weaken the section under shear but not greatly affect the section under bending. The use of 2 holes ½ and 1½ ft from the ground line should eliminate the possibility of a stub protruding from the ground after vehicular impact.

TEST RESULTS

The results of the 10 tests are given in Table 2 and shown in Figure 5. The tests were run in the order of test 1, 2, 9, 3, 8, 5, 10, 6, 7, and 4.

Tests 1, 2, 3, and 4: 6- by 6-in. Posts Supporting 5- by 10-ft Signs

In test 1 (Fig. 6) the sign dropped 2 ft and broke the windshield on the passenger side after the left post was sheared. Thereafter the sign pulled loose from the right

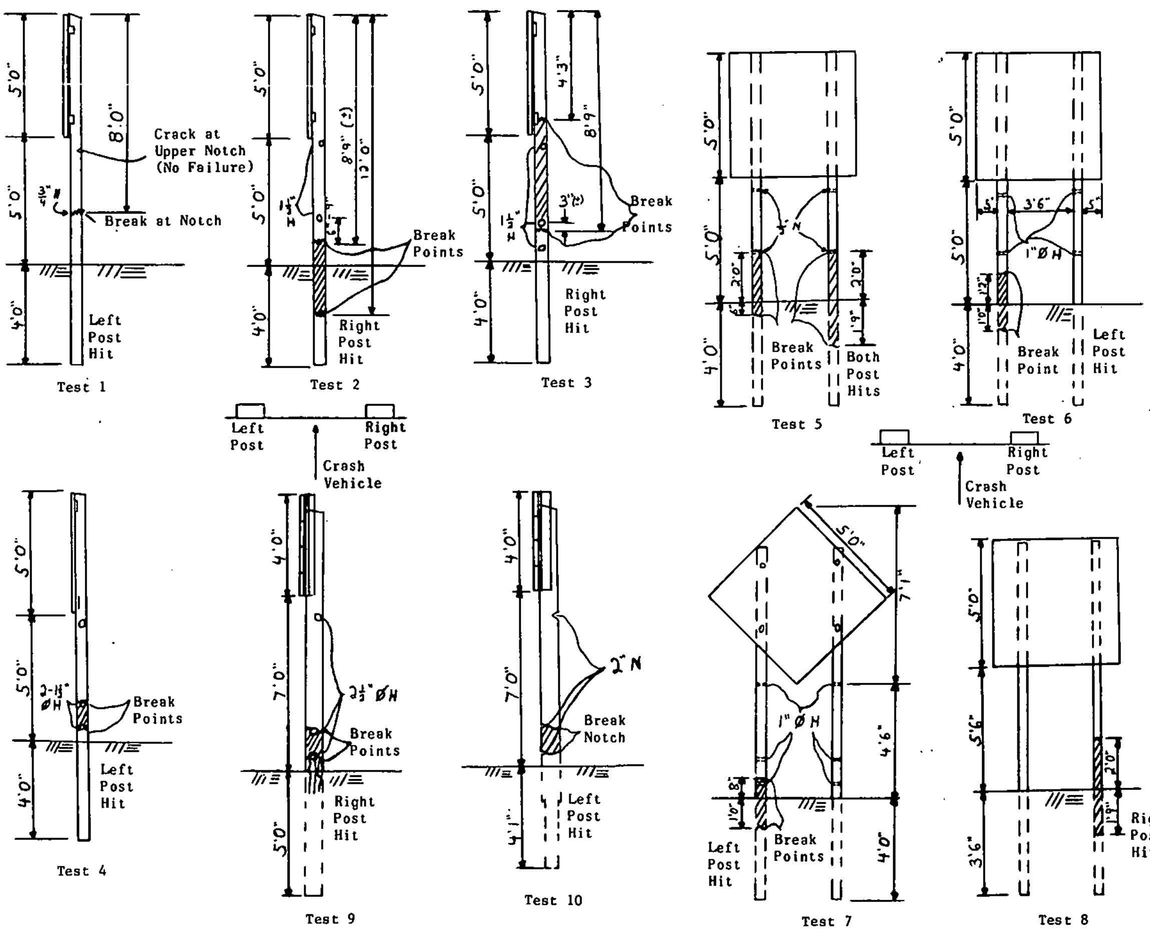

Figure 5. Location of signpost failures.

TABLE 2

SUMMARY OF SIGNPOST TESTS

Test	Post Hit	Plane of Weakness				Location of Failure[b] (ft)	Failure at Bottom of Post	Secondary Damage to Automobile
		Top		Bottom				
		Type[a] (in.)	Location[b] (ft)	Type[a] (in.)	Location[b] (ft)			
1	Left	$\frac{3}{4}$ N	$4\frac{1}{2}$	$\frac{3}{4}$ N	2	2	At bottom notch	Sign broke windshield
2	Right	$1\frac{1}{2}$ H	$4\frac{1}{2}$	$1\frac{1}{2}$ H	2	$1\frac{1}{4}$ -2	At knot In ground	Sign dented roof
3	Right	$1\frac{1}{2}$ H	$4\frac{1}{2}$	$1\frac{1}{2}$ H $1\frac{1}{2}$ H	$\frac{1}{2}$ $1\frac{1}{2}$	$5\frac{3}{4}$ $1\frac{1}{4}$	At stringer notch At knot	Sign dented roof
4	Left	2 H	$4\frac{1}{2}$	$1\frac{1}{2}$ H $1\frac{1}{2}$ H	$\frac{1}{2}$ $1\frac{1}{2}$	$\frac{1}{2}$ $1\frac{1}{2}$	At bottom holes	Sign completely smashed windshield
5	Both	$\frac{1}{2}$ N	$4\frac{1}{2}$	$\frac{1}{2}$ N	2	2 $-\frac{1}{2}$ to $-1\frac{3}{4}$	All notches In ground	Sign dented and tore roof
6	Left	1 H	$4\frac{1}{2}$	1 H	2	$1\frac{1}{6}$ -1	All bumper In ground	None
7	Left	1 H	$4\frac{1}{2}$	1 H 1 H	$\frac{1}{2}$ $1\frac{1}{2}$	$\frac{2}{3}$ -1	At knot In ground	None
8	Right	–	–	–	–	2 $-1\frac{3}{4}$	At knot In ground	Could not be determined
9	Right	$2\frac{1}{2}$ H	6	$2\frac{1}{2}$ H $2\frac{1}{2}$ H	$\frac{1}{2}$ $1\frac{1}{2}$	$\frac{1}{2}$ $1\frac{1}{2}$	At hole At hole	Post hit hood and roof
10	Left	2 N	6	2 N 2 N	$\frac{1}{2}$ $1\frac{1}{2}$	$\frac{1}{2}$ $1\frac{1}{2}$	At notch At notch	Post hit windshield

[a]H = Hole, N = Notch. [b]Referenced from ground line; minus indicates below ground line.

post but stayed attached to the sheared post by the top bolt. A longitudinal crack was observed in the sheared post at the root of the $\frac{3}{4}$-in. notch, the top plane of weakness.

The results from test 2 (Fig. 7) were significant because the left post, the sign, and the upper part of the sheared right post stayed together. The damage to the automobile was caused by the initial impact, and the sign dropped, slightly denting the car roof. If

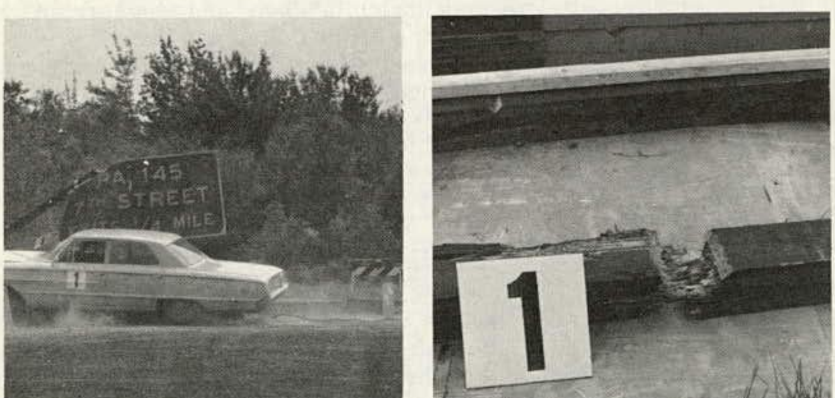

Figure 6. Test 1.

Figure 7. Test 2.

Figure 8. Test 3.

Figure 9. Test 5.

the sign installation had been mounted with more than 5-ft clearance between the ground line and the bottom of the sign, no further contact with the automobile would have resulted after the initial impact.

The sign dented the car's roof in test 3 (Fig. 8), and the sheared post also had a failure through the stringer notch above the bottom of the sign. The stringer notch is 2 by 4 in. and is more critical than the top plane failure, which was a $1\frac{1}{2}$-in. hole. The sign face and right post segment stayed with the left post. A piece of the right post hit the automobile's hood and was carried by it 80 ft from the original sign location.

In test 4, the sign dropped and completely smashed the windshield. The sign pulled loose from both posts as a result of its contact with the windshield. The failure of the sheared post was through both bottom $1\frac{1}{2}$-in. holes.

Figure 10. Test 8.

Tests 5, 6, 7, and 8: 4- by 4-in. Posts Supporting 5- by 5-ft Signs

In test 5 (Fig. 9), the most significant of this series of tests, both posts were sheared off at the bottom $\frac{1}{2}$-in. notches. The sign dented and tore the roof. The danger of such a collision with a convertible can easily be imagined.

The important aspect of test 6 is that the failure was at bumper height and was not caused by a weakened plane or knot. The fact that the post sheared through sound wood illustrates that a weakened plane is not necessary in 4- by 4-in. wooden signposts. The automobile used in this test was not used in any previous test, and no sign of damage could be observed.

The only difference between test 6 and test 7 was that a diamond sign was tested in test 7. The failure of the one post in this test was due to a knot.

Test 8 (Fig. 10) was supposed to show how a 4- by 4-in. post without any plane of weakness would shear near the ground. Unfortunately, so many knots were prevalent in both posts that it was impossible to exclude them from the bottom of the posts, and the plane of failure was through a knot.

Tests 9 and 10: 6- by 8-in. Posts Supporting 4- by 10-ft Signs

The installation for test 9 (Fig. 11) included a sign mounted with a 7 ft underclearance. The sheared right post pulled loose from the sign; however, the sign stayed attached to the left post. There was secondary contact with the automobile as the sheared post hit the hood and windshield liner, which caused very little damage, and this post segment was carried 120 ft down the runway

Figure 11. Test 9.

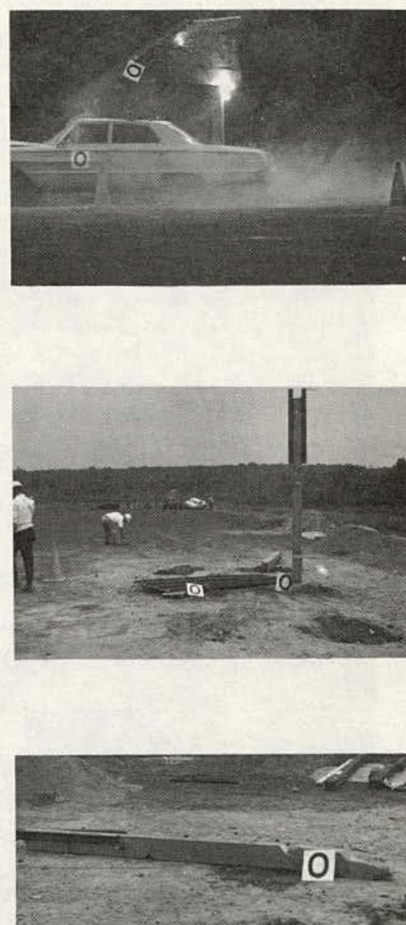

Figure 12. Test 10.

by the automobile. The post sheared at the 2 bottom $2\frac{1}{2}$-in. holes, with vertical splitting between the holes.

The size of the posts in test 10 (Fig. 12) was the same as those in test 9. The mechanism of failure was through both bottom 2-in. notches initially. After initial contact, the post momentarily stayed with the sign, which did not allow the post to rotate and clear the automobile. A secondary contact with the automobile occurred, and the sheared end of the post smashed the windshield on the driver's side.

DISCUSSION OF RESULTS

Failure occurred at the notches, bottom planes of weakness, in tests 1 (6- by 6-in. posts), 5 (4- by 4-in. posts), and 10 (6- by 8-in. posts) in all cases. Two notches were provided in test 10 and a piece of wood was chunked out similar to that in test 9. Where holes in the center of the post were substituted for the notches, shear failure was controlled by knots in the wood in test 2 (6- by 6-in. posts), and caused by the small section in test 6 (4- by 4-in. posts).

Two holes, bottom planes of weakness, were used in tests 3 (6- by 6-in. post), 4 (6- by 6-in. post), 7 (4- by 4-in. post), and 9 (6- by 8-in. post). In tests 4 and 9 a piece of wood between these weakened planes was chunked out thus demonstrating the usefulness of this technique. Test 3 was controlled by failure between the stringer notch and a knot; thus the provided planes of weakness could not be developed. Test 7 demonstrates that the presence of knots and small post sections makes it difficult to control the plane of shear failure. No plane of weakness was provided in test 8, and shear failure occurred through a knot. Five shear failures occurred at the induced planes of weakness, 4 at knots, and 1 through sound wood. In 5 tests the post that was hit broke below ground line.

The automobile was damaged by the sign dropping onto the windshield or roof in all the tests of 6- by 6-in. posts (Fig. 13). The underclearance between the ground and

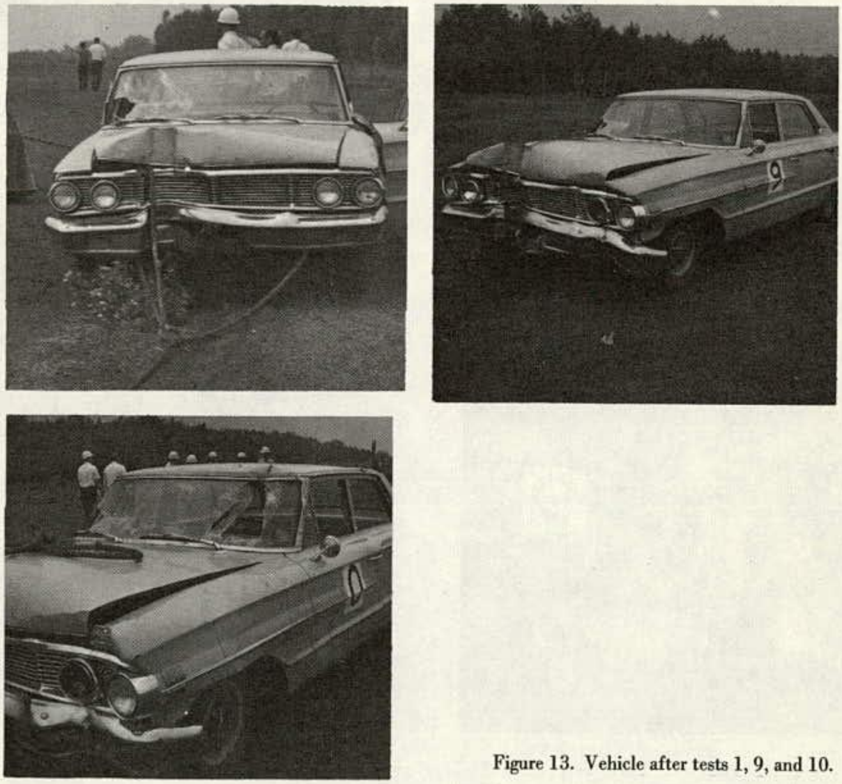

Figure 13. Vehicle after tests 1, 9, and 10.

the bottom of the sign should be increased from 5 ft to 6 or 7 ft. The sign in the tests of the 4- by 4-in. post did not contact the automobile after initial impact, except in test 5 when both posts were sheared. In tests 9 and 10 the 6- by 8-in. post struck the automobile in a secondary contact and in test 10 broke the windshield. This was caused by the more rigid sign-to-post connection.

The tests indicate that the sign-to-post connection was not sufficient to develop the upper plane of failure. This connection is made with $\frac{5}{16}$-in. diameter aluminum bolts on the 6- by 6-in. and 4- by 4-in. posts and with aluminum clamps on the 6- by 8-in. posts, which failed to hold the posts in the majority of the tests. If this plane of failure had been active, there is also the possibility of complete failure, thus creating a broken post segment that would be a potential safety hazard.

The ideal failure at the top of the post would be for the sign-to-post connection to be sufficient to hold the sheared post to the sign but allow it to rotate in order to prevent a secondary contact with the vehicle. Development of such a connection should be considered in some future investigation.

For failure at the bottom of the post, the use of 2 planes of failure $\frac{1}{2}$ and $1\frac{1}{2}$ ft from the ground gave the best shear zone. The 2 shear zones reduce the possibility of a long stub that might redirect an automobile in an actual collision.

These tests proved that holes are equivalent to notches (i.e., $1\frac{1}{2}$-in. hole to $\frac{3}{4}$-in. notch, 1-in. hole to $\frac{1}{2}$-in. notch, and $2\frac{1}{2}$-in. hole to 2-in. notch) in the bottom failure plane, if the effect of knots is excluded. The necessity of a top failure plane is questionable, and, because none of these actually failed, no direct comparison is possible.

CONCLUSIONS

The following conclusions are based on an analysis of the results of the field test conducted in this study:

1. The 5-ft underclearance of signs for 6- by 6-in. and 4- by 4-in. post installations was not sufficient to prevent secondary contact with the automobile.
2. The location of the bottom plane of weakness using 2 holes spaced at $\frac{1}{2}$ and $1\frac{1}{2}$ ft from the ground line, parallel to the sign face, gave comparable results to notches at the same location.
3. Holes in posts are superior to notches because the post splits through the holes on vehicular impact and has greater capacity to resist wind loads (test 9).
4. The top plane of weakness did not function.
5. A desirable failure mechanism is the formation of a pivot point at the top sign connection when one post of a two-post sign is sheared off, as in test 2.
6. The more rigid sign connection in tests 9 and 10 did not allow sufficient post rotation to take place.
7. Because of their small sections, 4- by 4-in. posts do not require any induced planes of weakness (test 6).
8. The knots prevalent in wooden posts affect the failure mechanism.

RECOMMENDATIONS

1. Signs should be mounted so that the minimum clearance from the ground to the bottom of sign is 6 ft and preferably 7 ft.
2. The only plane of weakness should be $2\frac{1}{2}$-in. diameter holes in 6- by 8-in. posts and $1\frac{1}{2}$-in. diameter holes in 6- by 6-in. posts spaced at $\frac{1}{2}$ and $1\frac{1}{2}$ ft from the ground line.
3. Posts with 4- by 4-in. cross sections should not be so altered.
4. Strong bolts should be used to make the sign-to-post connection for 6- by 6-in. posts.

FUTURE RESEARCH

Future research should consider the following items:

1. A better failure mechanism such as a pivot point at the top sign connection should be developed and tested.

2. Tests should be conducted on wooden posts embedded in concrete and a sign mounted higher to evaluate the effects of both.

ACKNOWLEDGMENT

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